Approximate Positions.

	C.U.T. h m	R A. h m s	S. Dcl. ° ′ ″
March 13	8 5	1 22 45	−15 40
17	8 0	1 7	−11 11
20	8 0	0 59 25	8 23 30
22	7 15	0 55 25	6 29 30
23	7 15	0 53 22	5 32 30
24	6 4	0 51 10	4 44
25	6 25	0 49 31	3 54 30
26	6 30	0 41 40	3 5 30

Instrument $9\frac{1}{4}$-inch reflector by Calver.
Powers 60 and 100.

Grahamstown,
1899 *April* 2.

Notes on the Spectra of γ Cassiopeiæ and o Ceti.

By the Rev. Walter Sidgreaves, S.J.

γ Cassiopeiæ.

The photographs of the spectrum of *γ Cassiopeiæ* obtained at this observatory are distributed over a period of eight years. There are fifty-two plates all told, of which half are by the old 8-inch glass and half by the Perry Memorial Objective of 15 inches aperture. With few exceptions they are all good photographs; but one of exceptional definition, of date 1898 March 7, was selected for the micrometer. From this plate the chart of the spectrum and table of wave-lengths were first constructed. The remaining plates were then examined, and it was found that with the guidance of the better plate nearly all the tabulated details could be traced also in the photographs of inferior definition.

It was not so easy to form a conclusion upon the general spectrum independently of the results of other observers. It might be in general a bright line or a dark line spectrum, but in either case it should be described as composed of hazy and weakly looking lines and bands. That there were some absorptions could hardly be doubted; the blue Hydrogen line H_γ appeared to be clearly resting on an absorption band; the Helium lines 4025 and 4471 and a line in the green 5295 were also absorptions. But for the rest, the condition of H_δ at one end of the spectrum and of the Magnesium group at the other were in favour of bright lines. The Hydrogen line seemed to have no

greater claim to be called bright than many of its neighbours; and in the Magnesium group it was the silver deposit, not an intervening space, which fell to the wave-length 5170, which is the mean of the group. Influenced by these considerations, a table of wave-lengths was made out on the supposition of a bright line spectrum, and compared with the tabulated lines of other stars. It was then seen that many of the *Orion* lines, including all the Helium lines, agreed better with the spaces between the bright lines than with the lines tabulated. Another table was then made out for the lines, on the supposition of an absorption spectrum; but it was found impossible in this operation to avoid tabulating many bright lines, and the result obtained is a mixed spectrum of bright and dark lines.

The General Spectrum.—The complete spectrum of the star is given in tabular form, with the bright lines indicated by the letter *b* written after them; and in a parallel column the absorption lines of γ *Orionis*, as measured on a plate of date 1896 December 28, are entered for comparison. It will be observed that both dark and bright lines of γ *Cassiopeiæ* are fairly well matched by *Orion* lines. An asterisk (*) means that the line is near an *Orion* line not seen in γ *Orionis*. A dagger (†) means that the line is not contained in Pickering's list of *Orion* lines.

The Hydrogen Spectrum.—The following figures, collected from the tabulations of the general spectrum, exhibit the Hydrogen spectrum separately, with the character and relative intensities of the lines :—

	Hε.	*i*	Hδ.	*i*	Hγ.	*i*	Hβ.	*i*
Absorption	3963	6−	4095	5−	4334	4−		
Radiation	3970	0	4101	2	4340	8	4861	10.
Absorption	3976	6_	4107	5_	4347	4_		

The extreme figures in each case indicate, in wave-lengths, the margins of the broad absorption bands. It will be noticed that the intensity assigned to the radiation H_ϵ is zero. This means that the silver deposit is about the same as that of the continuous spectrum, and the line appears by contrast on the broad absorption. H_δ is stronger than the continuous spectrum, and H_γ much more so. All three have the same appearance of a reversal in the centre of a broad absorption line; but H_β is superlatively bright, with only a very weak, if any, absorption background. The radiation or bright lines increase in intensity with increasing wave-length, while the absorptions fall off. The Hydrogen spectrum therefore of γ *Cassiopeiæ* is very closely the same as described by Professor Pickering in the "Harvard College Annals" in 1897,* and differs from Sir Norman Lockyer's photographs only in the appearance of H_β, which on the South Ken-

* XXVIII. i. 100.

sington plates appears superposed on a broad dark band.* And this difference is probably due to the smaller dispersion employed at Stonyhurst. On some plates by greater dispersion the dark H_β is well marked, but not strongly.

That the bright Hydrogen lines are doubles has been shown by Lockyer, Newall, and McClean. They are not represented so either on the map or in the table of wave-lengths, both of which were constructed from a photograph too small to show the separation. On other plates with the greater dispersion of two compound prisms H_γ has the convincing appearance of a double, inasmuch as it appears not stronger at the centre than at the margins of a comparatively broad line; and on one plate the middle of the line is decidedly weaker.

The Helium Spectrum.—In the following table the Helium lines, as published by Runge and Paschen,† are collated with absorption lines in *γ Cassiopeiæ* :—

Helium.		γ Cassiopeiæ.		Helium.		γ Cassiopeiæ.	
λ	*i*	λ	*i*	λ	*i*	λ	*i*
4009	1	4009	5	4438	1		
4026	5	4025	6	4471	6	4471	6
4121	3	4118	3	4713	3	4711	1
4144	2	4144	4	4922	4		
4169	1	4170	3	5016	6		
4388	3	4388	4	5048	2	5048	2

The Bright Lines.—The supposed Magnesium group at 5170 as a bright line group is confirmed by the high temperature Magnesium line at 4481 appearing also as a bright line. This cannot well be taken for the Iron line 4481·6, because it would be the only strong Iron line in the spectrum of the star out of many equally strong lines in the Iron spectrum. Sherman ‡ has the 5170 line at 516·75, which is a nearer match to the head of the Carbon band at 5165 than our line at 5170, but it is quite impossible to reduce the wave-length we have tabulated.

The lines 4518 and 4586 are those noted by Pickering as examples of "bright regions which are not well defined bright bands, . . . but have rather the nature of bright spaces between dark lines." § Our judgment of them is strongly in favour of true bright lines. The longer wave-length of the two is the brightest line in the spectrum after H_γ, and on some plates its appearance suggests that it would resemble H_γ very closely if it were set off on a similar absorption background.

The line at 5020 is the line noted by Pickering at 5023 as the strongest of the bright lines not due to Hydrogen, and he does not speak of bright 5170; on our plates these two lines are of equal bright intensity.

* *Proceedings of the Royal Society*, lvii. 176.
† *Astrophysical Journal*, iii. 10.
‡ *Astr. Nach.* No. 2707.
§ *Harvard College Annals*, XXVIII. i. 101.

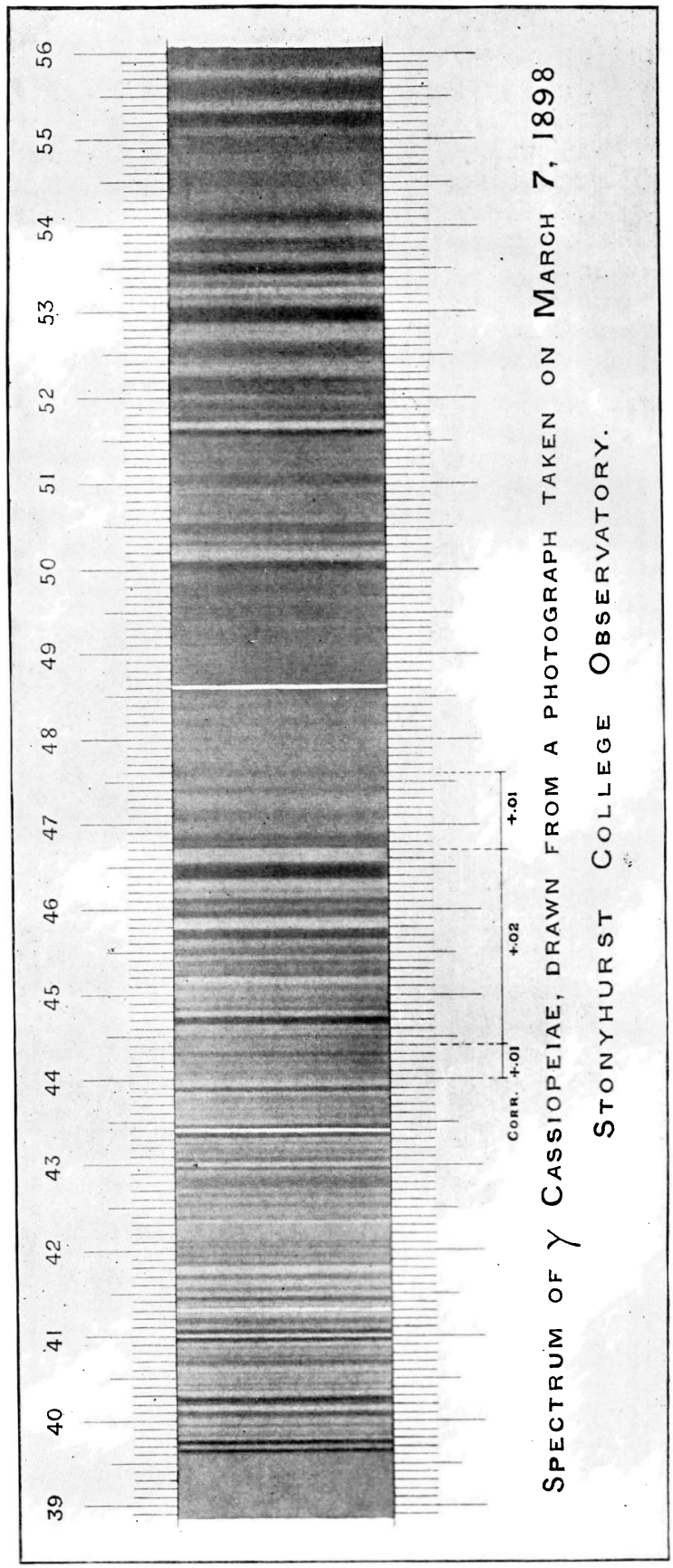
Origins.—Excepting Hydrogen, Helium, and Magnesium, there are no very probable origins assignable. The strongest bright line, already mentioned at 4586, might be attributed to Vanadium, if the stronger lines of the metal made a better figure in the spectrum of the star; but the lines that should be the strongest are the weakest. The following table shows how they are matched in an inverse order of their intensities :—

Bright Lines. γ Cassiopeiæ.		Vanadium (Thalén).	
λ	*i*	λ	*i*
4382	1	4379·0	10
		4384·1	10
4395	2	4395·1	6
4586	6	4585·1	4

Variability.—The Hydrogen spectrum has shown no signs of alteration during the eight years of observation, but in other parts of the spectrum there is a probability of changes. These in general are not sufficiently pronounced to safeguard our conclusions against erroneous changes, which may be due only to atmospheric effects upon the photographic definition. But the strong bright (Vanadium ?) line 4586 appears on several plates with a greater probability of real change. On some plates it is a clear single strong line; on others its appearance is that of a double, too close for separation by small dispersion and of less intensity, with the apparent widening all on the side of shorter wave-length. Real change may account for this line escaping the notice of Sherman at Yale College, and for its appearance on the Harvard College plates as inferior to the line 5023. Our measure of this latter line is 5020, the same as Sherman's dark line 502. Its brightness is noted as varying between 1 and 4, which may be attributed to photographic imperfections; but as a dark line recorded by Sherman, and as a bright line on the photographic plates at Harvard College and Stonyhurst, it claims to be a variable.

The following comparisons with Sherman's lines will serve to show where possible changes may be looked for, bright lines and dark lines being distinguished by the letters *b* and *d*. But the unlettered figure 5275 represents a space between absorption lines :—

Yale.	Stonyhurst.	Yale.	Stonyhurst.	Mean.
399·3 *d*	3995 *d*			
418 *b*	4177 *b*	530·98 *b*	5275 5316 *b*	5296
462·3 *b*	4628 *b*			
467·3 *d*	4681 *d*			
492 *d*	4711 *d*	542·2 *b*		
499 *b*				
502 *d*	5020 *b*		5540 *b*	
516·75 *b*	5170 *b*	555·75 *b*	5576 *b*	5558



o Ceti.

During the recent period of maximum brightness of *o Ceti* in the autumn of 1898, the weather was far from favourable, and only seven out of thirteen exposures gave good photographic spectra of the star. These are stronger than the photographs obtained in the previous maximum period, owing to the greater magnitude attained in 1898. The spectrum is the same in all its details, with the single exception that the possible bright line at 4862 appears in much stronger contrast than in 1897, and under conditions of defective definition which would then have completely obliterated it. But apart from its position of the H_β radiation, it could not be called a bright line. H_γ and H_δ retain their extraordinary brilliancy, with a possible increase of difference between the two intensities in favour of H_γ.

A wave-length correction which affects the tabulations and chart of the spectrum of *o Ceti*, as given at pages 346–352, vol. lviii. *Monthly Notices*, between λλ 4400 and 4760, has been found necessary. The conclusion was drawn from the comparison columns of *γ Cassiopeiæ* and *γ Orionis*. In both columns the Helium line 4471 appeared at 4469. Six other *Orion* star spectra were then measured, and each gave the line at 4469. But two of these had been also photographed with a two prism dispersion, and these gave the line at 4471. The two-prism wave-length-curve was then carefully re-examined with the aid of Dr. Scheiner's tabulated solar lines in *α Aurigæ* and Rowland's map of the solar spectrum. A large number of these lines were satisfactorily identified on the two-prism photograph of the spectrum of *Arcturus*, and were found, by the curve, to agree with Scheiner's figures to nearly the fifth figure. The shorter, or one-prism curve, was then corrected by the longer one, through the medium of the same star spectra as given by the one-prism and by the two-prism dispersions. The spectra employed were of *α Boötis*, *η Ursæ Majoris*, and *α Cygni*. The resulting corrections * are to the fourth figure—

+ 1	between	4400	and	4440
+ 2	,,	4440	,,	4670
+ 1	,,	4670	,,	4760

These corrections, applied to the tabulations of *o Ceti* from the photographs of 1897, improve their relations to the strong metallic

* This correction is applicable to the tabulations of *β Lyræ*, 1895, but not to those of 1893, nor to those of the *Nova*, 1892, which were by another instrument.

lines; and the middle subdivision of the band which begins at λ 446 is brought nearer to the strong Helium line 4471·6.

The Hydrogen Spectrum of o Ceti and of γ Cassiopeiæ.—The bright Hydrogen lines of *γ Cassiopeiæ* seem to exhibit the same character of radiation as that of the electrified Hydrogen tube of the laboratory. In both, the density of the silver deposit upon the photographic plate is greatest by H_β radiation and decreases with the shorter wave-lengths. The two brilliant lines of *o Ceti*, H_γ and H_δ, do not appear to follow the same law, H_δ being far too strong compared with H_γ; but this may be accounted for by the greater strength of the continuous spectrum about H_γ showing less contrast. And this explanation is made more probable by a smaller photograph with a single half-prism, in which the H_γ line is almost lost in the condensed continuous spectrum of its neighbourhood. If we suppose the relative intensities of the lines of *o Ceti* as they appear on the plate without reference to the sensibility curve to be the same as found in the laboratory, it is not easy to imagine the condition of things able to stop out so powerful a radiation as that of H_β. Another query suggests itself: Where is the absorbing atmosphere capable of stopping out H_ϵ, H_β and H_α? Dr. Scheiner's suggestion for *γ Cassiopeiæ*, of a Hydrogen atmosphere great compared with the photosphere of the star, is the only one which seems reasonable, if we limit our thoughts to our present knowledge of spectroscopic phenomena. The explanation fits the observations of *γ Cassiopeiæ* very satisfactorily. The denser Hydrogen near to the photosphere would give the broad dark bands, and the rarefied Hydrogen more remote from the centre would give the bright reversal in the middle. The other lines, bright and dark, would respectively indicate elements *diffused* through the Hydrogen atmosphere, and others *low-lying only*; a supposition well in keeping with the appearance of the lines, which is that of a struggle between radiation and absorption to impress its mark on the plate. But when applied to *o Ceti* the explanation only adds new puzzles to the already perplexing spectrum of the star. In this spectrum we have Hydrogen radiation far more intense than in *γ Cassiopeiæ*. We have ink-black broad absorptions, and a brilliant photospheric spectrum. To account for the glowing Hydrogen lines we have to suppose either a far more vast Hydrogen atmosphere or a greatly higher temperature; and for the missing lines we need dense vapours at lower temperatures and co-extensive with the Hydrogen atmosphere. It seems preferable to go beyond our laboratory knowledge and suppose an abnormal Hydrogen radiation of a high degree of energy in which some of the oscillation frequencies have fallen out of the spectrum.

γ Cassiopeiæ. λ	*i*	γ Orionis. λ	*i*	γ Cassiopeiæ. λ	*i*	γ Orionis. λ	*i*
3963	6					4393	1
3970 *b*	0	3970	10	4395 *b*	2	4399	1
3976	6					4409	1
						4418	2
		3980	1	4431	3	4428	1
3983	1	3985	1			4439	2 *d*
3995	2	3995	1	†4451	1		
4009	5	4008	7			4457	1 *d*
		4016	2	†4462 *b*	1		
4025	6	4026	9	4471	6	4471	6
		4033	1			4478	1 *d*
*4037	1			4481 *b*	2		
4043	1	4043	1 *d*	†4485	1		
		4053	1			4492	1 *d*
		4059	1			4506	1
4069	3	4068	1	4518 *b*	3	4517	1
		4072	1			4532	1
4076	2	4076	1			4543	1
		4085	1			4552	2
4088	1	4090	1 *d*			4569	2
				4573	4 *w*	4579	1
4095	5			4586 *b*	6 *w*		
4101 *b*	2	4097	2			4593	1
4107	5	4101	10	*4596	3	4606	1
				*4612	3		
		4111	1			4621	1
4118	3	4121	5	4628 *b*	4 *w*	4632	1
		4129	2	4647	6 *w*	4643	2
4131 *b*	3	4131	1			4652	2
		4135	1	4664 *b*	4 *w*	4664	1
4144	4	4145	7	4681	3 *w*	4678	1 *d*
4155	1	4153	1 *d*			4697	2
		4162	1			4705	1
4170	3	4169	3	4711	1	4713	2
†4177 *b*	2					4731	1
4185	2	4186	1			4738	1
		4198	1			4746	1
		4204	1			4760	2
		4211	1			4782	1

γ Cassiopeiæ. λ	*i*	γ Orionis. λ	*i*	γ Cassiopeiæ. λ	*i*	γ Orionis. λ	*i*
		4225	1			4796	2
†4234 *b*	2					4821	1
4239	1 *d*	4238	1			4839	2 *d*
		4248	1	4861 *b*	10	4861	10
4253	1	4255	1			4871	2
4266	1	4268	3			4885	3
		4275	1			4902	3
4281	2 *w*	4282	1			4923	6
		4289	1	5006	3		
4295	2	4295	1	5020 *b*	4 *d*		
4302 *b*	2	4304	1	5048	2		
4306	2			5104	2		
4317	1	4317	1	5160	3		
		4323	1	5170 *b*	4		
4326	1	4328		5214	3 *w*		
				5256	3 *w*	5254	5
4334	4			5295	4 *w*		
4340 *b*	8	4340	10	5316 *b*	2		
4347	4			5350	4		
		4353	1 *d*	5376	3		
		4364	2	5411	3		
		4374	1	5524	3		
*4382 *b*	1			5540 *b*	2		
4388	4	4388	5	5576 *b*	2		

b = bright line. *w* = wide line. *d* = double line.

The region beyond λ 4923 of γ *Orionis* has not yet been completely mapped.

Stonyhurst College Observatory.